

AN ACOUSTIC STUDY OF THE JAPANESE SHORT AND LONG VOWEL DISTINCTION

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Abstract

The present study concerns the vowel length distinction between Japanese short and long vowels. Previous studies (Han 1962, Hirata 2004, Kozasa 2005) concluded that short and long vowels differ from each other in terms of duration and pitch fall; that is, long vowels are about 2.4 times longer than short vowels, and long vowels have a pitch fall within a word while short vowels do not. Most studies confirmed the differences between short and long vowels when they are accented. However, none of the previous studies has investigated the differences between short and long vowels using the same test words when a vowel is unaccented; that is, when a pitch fall is absent. The present study concerned the environment where there is no pitch fall within the target vowel: the compound noun context; where HL pitch accent becomes HH, and H becomes L. An acoustic study was conducted in order to investigate the difference between short and long vowels in Japanese in two different contexts, the accented context, and the unaccented context, in which the target word is compounded with the suffix [jo:] in order to neutralize the pitch accent High (H) to Low (L) and HL to LL. The target vowels in the accented context are labeled H for short and HL for long vowels, and the ones in the unaccented context are labeled L for short and LL for long vowels. A wordlist reading task was used for the production study. Measurements were made for pitch onset (F0 value at onset of target vowel), pitch offset (F0 value at offset of target vowel), pitch fall (onset- offset), vowel duration, F1, F2, F3. Analyses showed that F0 neutralization in the unaccented context was incomplete as measured by F0 onset and F0 offset. However, pitch neutralization from H to L as measured by pitch fall was observed. In addition, long

vowels were longer than short vowels, and longer in the unaccented context than in the accented context. Pitch fall was significantly larger in the accented context and statistically nonexistent in the unaccented context. Although accented vowels were significantly longer than unaccented vowels, the ratio of short and long vowels was 1:2.4 and 1:3.2 in accented and unaccented contexts, respectively. The difference between short and long vowels was larger in the unaccented context. In terms of vowel quality, F1, F2 and F3 all three significantly differed between short and long vowels in both the accented and unaccented contexts. F1 was significantly higher in the accented context than in the unaccented context and the difference between short and long vowels was significantly larger in the unaccented context. F2 was significantly lower in the accented context than in the unaccented context and the difference between short and long vowels was significantly larger in the unaccented context. The F3 difference between short and long vowels was significant in both accented and unaccented contexts. This difference, however, was larger in the accented than the unaccented context unlike F1 and F2. When vowels were unaccented, the speakers showed larger differences between short and long vowels in F1 and F2, presumably due to the lack of pitch fall.

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Chapter1. Introduction and Literature Review

1.1 Introduction

Many languages have phonological distinctions of quantity in vowels, consonants or both. For example, Japanese is well known for its vowel and consonant length contrasts. In Japanese, phonological length is counted by mora, e.g., short vowels carry one mora and long vowels two, and singleton consonants carry one mora and geminate consonants two. Finnish also has a length distinction for both consonants and vowels (Abramson and Ren, 1990). Italian is known for its intervocalic short-long consonant distinction in word-medial position, while Pattani Malay is known for its word-initial prevocalic short and long consonants (Abramson, 1987). Swedish and Thai have phonemic contrasts between short and long vowels (Hadding-Koch and Abramson, 1964; Abramson and Ren; 1990). Relative duration could be a physical correlate of the length distinction in phonetic segments. This fact would lead us to suppose that the articulatory configuration is held longer for the “long” segment than for the “short” one (Abramson and Ren, 1990).

Vowel duration is the clearest cue to vowel length differences in most of the languages that have a vowel length distinction. Research has been conducted on vowel duration in many languages. The classic study in Japanese by Han (1962) concluded that the ratio of short vowel and long vowel duration is about 1: 2.5, and most of the recent studies in Japanese agree with her results. Han reported that the vowel duration ratio for [i] and [i:] was 1:2.0, for [bo] and [bo:] was 1: 2.5, for [se] and [se:] was 1: 3.0. However, the number of speakers and the methods of segmentation are not clearly mentioned in her study. As mentioned above, Swedish is also known to have a phonemic vowel length

distinction that plays an important role in the phonological system (Hadding-Koch and Abramson 1964; Elert 1964). Although quality differences in pairs do exist, they are generally assumed to be secondary to the length difference (Elert 1964, Hadding-Koch and Abramson 1964). Hadding-Koch and Abramson concluded that the duration ratio of [e] and [e:] is 1:1.77, [u] and [u:] is 1:1.25, [o] and [oe] is 1:1.85.

Abramson and Ren (1990) examined the Thai vowel system. They used five minimal pairs, /i/ and /i:/, /e/ and /e:/, /a/ and /a:/, /u/ and /u:/, /o/ and /o:/. The test words were read by one adult native male speaker. Their results showed that overall, long vowels were 1.9 times longer than short vowels. The mean durations of the short vowels and long vowels were 85 ms and 165 ms, respectively. There was no overlap between the short vowels and long vowels.

The other acoustic correlate of the vowel length distinction is vowel quality. However, it is said that vowel quality of short and long vowels does not differ dramatically in languages that have a vowel length distinction (Jones 1950). For example, vowel quality showed some differences in Swedish, although [u] and [u:] showed a larger difference than other vowels; however, it was not as clearly different as vowel duration (Hadding-Koch and Abramson 1964).

The study by Abramson and Ren (1990) also showed differences between short and long vowels in vowel quality. The results from their formant frequency study can be seen in Table 1.

	F1	F2	F3
/i/	318	2028	2635
/i:/	270	2150	2820
/e/	415	1970	2528
/e:/	380	2068	2565
/a/	845	1543	2620
/a:/	838	1563	2710
/o/	480	1155	2608
/o:/	475	965	2595
/u/	368	1105	2430
/u:/	305	800	2530

Table 1. Formant frequencies of the Thai short and long vowels in
Abramson and Ren (1990, p 83)

The authors found that the short vowels have a higher F1 and a lower F2 for the front vowels. For the back vowels, not only is F1 higher in short vowels, but so is F2. However, for the /a/ and /a:/ pair, F1 and F2 were not significantly different, while F3 was higher in the long vowel. A drawback of this study is that it included only one participant and two tokens for each test word.

Another acoustic correlate of vowel length is fundamental frequency (F0). Several studies done in Japanese have claimed that pitch falls within a long vowel, that is, there is a pitch movement from H (high) to L (low). Kozasa (2005) examined the difference in pitch fall value between short and long vowels in Japanese. Her results showed that long vowels have a larger pitch fall than short vowels.

From the studies discussed here, it is clear that vowel duration is not the only acoustic correlate of the phonemic vowel length distinction. In the following section, I will consider the relevant previous work done in Japanese in more detail.

1.2 Literature Review

1.2.1 Vowel Duration

It is widely said that the main acoustic correlate of the phonemic short and long vowel distinction is vowel duration (Han 1962, Hirata 2004, Kozasa 2005), although small differences were observed in terms of vowel quality of short and long vowels (Kondo 1995). Han (1962) examined durational differences between Japanese short and long vowels. She mentioned examples of minimal pairs such as [i] 'stomach' and [i:] 'good', [e] 'picture' and [e:] 'yes', [obAsAn] 'aunt' and [obA:sAn] 'grandmother', [ojisAn] 'uncle' and [oji:sAn] 'grand father', and [soshiki] 'system' and [so:shiki] 'funeral'. However, the actual minimal pairs that she used for the experiment are not clearly shown, nor are the durational values. Her results showed that the ratio of short and long vowels [i] and [i:] is 1: 2.0, [o] and [o:] in /bo/ and /bo:/ is 1:2.5, and [e] and [e:] in /se/ and /se:/ is 1: 3.0. The author mentioned that she also looked at vowel quality and did not observe any significant differences. However, she did not present any results.

Isei-Jaakkola (2004) investigated three Tokyo Japanese speakers, and the speakers were asked to produce nonsense test words with the vowel /A/ (see Table 2).

Syllable Structure			
CVCV	mama	papa	sasa
CVCVV	mama:	papa:	sasa:
CVVCV	ma:ma	pa:pa	sa:sa
CVVCVV	ma:ma:	pa:pa:	sa:sa:
CVCCV	mamma	pappa	sassa
CVCCVV	mamma:	pappa:	sassa:
CVVCCV	ma;mma	pa:ppa	sa:ssa
CVVCCVV	ma:mma:	pa:ppa:	sa:ssa:

Table 2. Test words used in Isei-Jaakkola. Adopted from Isei-Jaakkola (2004, p. 41)

The test words were read in the carrier sentence *Mo:ikkai _____ to itte kudasai* 'Please say _____ once more.' The mean duration of short /A/ was 80 ms and that of long /A:/ was 199 ms. The ratio of short vowel to long vowel duration was 1: 2.5.

There have been some studies on the relationship between Japanese vowel duration and Japanese pitch accent. Before discussing prosodic correlates of Japanese vowel length, let us consider the Japanese prosodic system. Japanese vowels can have two prosodic features: length and pitch accent (Kozasa 2005). The duration of long vowels is phonetically longer than that of short vowels. The phonological vowel length is counted in terms of moras; that is, short vowels carry one mora, and long vowels carry two moras (McCawley 1968).

Another prosodic feature in Japanese is pitch accent (Sugito 1982, Vince 1985, Fujisaki et al. 1988, Beckman and Pierrehumbert 1988). It is said that when words contain a high (H) and low (L) pitch sequence (HL), they are accented, as can be seen in example (1) below

(1)

a. kA 'section'

|

H unaccented

b. kA 'mosquito'

|

L unaccented

c. kA : 'car'

| |

HL accented

(1a) and (1b) are unaccented since there is no HL sequence within the word. (1a) has an H; if there is no L following, it is considered unaccented. (1c) is a good example of how pitch accent can be contrastive in Japanese. It shows that if there is a HL sequence within a long vowel, it is considered accented.

Recently, Hirata (2003, 2004) investigated the relational acoustic invariance of Japanese vowels. She examined relative vowel duration in two conditions: accented and unaccented. Hirata (2004) used accented minimal pairs that consisted of real Japanese words. For example, Hirata compared the vowels /o/ and /o:/ in the accented pair [toshō] (H.L) 'books' and [tō:shō] (HL.L) 'the beginning,' and in the unaccented pair [kAto] (H.L) 'transition' and [kAto:] (H.LL) 'surname'. The test words consisted of five Japanese vowels [i], [e], [A], [o], [∞] in two-mora or three-mora words and contained the same consonant preceding the target short or long vowels, but the other segments varied. Hirata's results showed that long vowels were longer than short vowels across all speech rates. The average ratio between short and long vowels was 1: 2.51 for accented, and 1: 2.22 for unaccented vowels. Hirata concluded that long vowels are longer than short vowels whether or not the vowels are accented or unaccented. However, Hirata's results

do not directly address differences between short and long vowels in the accented and the unaccented context since the location of the target vowels was different in the two contexts.

Kozasa (2005) used 25 minimal pairs that included all of the five Japanese vowels such as [A:rœ] 'R' and [Arœ] 'to exist', [kA:do] 'card' and [kAðo] 'corner', [se:to] 'student' and [seto] 'Seto (place name in Japan),' with HL pitch for long vowels and H for short vowels. She also had unaccented words with HH pitch for long vowels and H for short vowels, such as [se:ko:] 'success' and [seko:] 'construction'. However, she noted that the "the accent pattern for these lexical items may differ from dictionary entries, because when a syllable with a long vowel occurs initially in an accentual phrase (AP), the first mora is always realized with a low phrasal accent. Consequently, it creates a LH pitch-contour within the long vowel, which is the accent pattern shown in the dictionary. However, since these words were read in a carrier sentence, syllables with a long vowel did not occur AP initially; thus, the pitch contour stayed HH, which was supported by Fujimura (personal communication)" (Kozasa 2005, p.83). However, according to McCawley (1968), when a long vowel is accented a HH sequence cannot be assigned, but H must be assigned to the first mora and L pitch must follow the first mora within a long vowel; that is, there must be a HL pitch sequence when a long vowel is accented. When a vowel is not accented, the pitch could remain HH within a long vowel in a phonetic account, not a phonological account. Consequently, Kozasa's results showed two phonetic features in accented long vowels in Japanese: longer duration and F0 pitch fall within the vowel. While Kozasa (2005) investigated the differences between short and long vowels in accented and unaccented words, her account for the unaccented condition

that focuses on target words in the carrier sentence is not clear. The claim that the LH pattern within a word changes to HH when placed in a carrier sentence is questionable since many native speakers of Japanese insert a small pause after adverbs and particles when they pronounce them. Kozasa's carrier sentence starts with 'sakki' which is an adverb meaning 'a little while ago'. Therefore, it is highly likely that her speakers did not change the LH pitch to HH during the reading task.

Two male and two female participants were recorded. Each word pair was embedded in a different carrier sentence. For instance, *sakki 'a:ru' to iimashita* 'I said R a while ago' and *sakki 'aru' to iimashita* 'I said aru a while ago', and *sono 'ka:do' fuite* 'Please clean up the cards' and *sono 'kado' fuite* 'Please wipe that corner.' Results showed that the mean duration of the short vowels was 100 ms, and the mean duration of long vowels was 177 ms. The ratio between short and long vowels was 1:1.77. The long vowels were significantly longer than their short counterparts.

1.2.2 Pitch accent

Homma (1973) examined whether pitch accent had any influence on Japanese vowel duration. She used two moraic test words with the Kyoto accent and measured F0 and vowel duration of V₁ and V₂ in the CV₁CV₂ context, and compared V₁ and V₂ in both an accented context HL and an unaccented context HH or LH¹. The words that Homma used included [hAnA] (H.L) 'flower', [hAnA] (L.H) 'nose', [kAki] (L.H) 'fence' and [kAki] (H.L) 'case'. Her results showed that V₂ was consistently about 20 ms longer than

¹ She also mentioned that she used words with /H-HL/. However, since there is no such pitch contour in Standard Japanese, which the present study will be investigating, I do not mention it here.

V_1 , and this was true across all three different pitch patterns. This suggested that pitch accent had no significant effect on vowel duration in Japanese.

On the other hand, Homma (1973) showed that F0 showed different results. The difference between V_1 and V_2 ($V_1 - V_2$) was 100 Hz for /H.L/, 21 Hz for /H.H/ and -24 Hz for /L.H/. This suggests that: (1) The sequence of H and L has the largest F0 difference; (2) Even though the pitch sequence is H followed by another H, the F0 does not stay flat, but it falls about 20 Hz; (3) The sequence of LH has a much smaller difference than that of HL. However, no long vowels in comparison to short vowels were used in this study.

1.2.3 Vowel quality

Kasuya et al. (1968) investigated the difference in formant frequency of the five short Japanese vowels by age and gender. Their participants were eleven children, and four adults. Their findings indicated that most of the Japanese vowel formants were affected by the age and sex of speakers depending on the vocal tract length (see Table 4).

However, F3 of /i/, which mainly relates to the front part of the vocal cavity, was almost consistent across age and sex, and so were F1 and F2 of /o/, which constitutes a lip-rounding configuration. The difference between male and female F1 and F2 becomes distinct after the age of 11, while F3 is distinctive at an earlier age; after 9 years old. The primary difference between male and female was F3 (see Table 3).

		F1	F2	F3
/i/	Child	393	3215	3860
	Boy	317	2622	3183
	Female	325	2725	3475
	Male	263	2263	3000
/e/	Child	659	2468	3574
	Boy	500	1900	2700
	Female	483	2317	2983
	Male	475	1738	2400
/A/	Child	1072	1609	3699
	Boy	805	1296	2936
	Female	483	1363	3050
	Male	475	1163	2713
/o/	Child	593	1077	3597
	Boy	475	868	3000
	Female	483	925	3000
	Male	550	838	2625
/œ/	Child	428	1537	3323
	Boy	339	1389	2596
	Female	375	1675	2688
	Male	363	1300	2350

Table 3: Formant frequency data for Japanese short vowels produced by children, boys, and adult females and males (from Kasuya et al. 1968, p 359)

I have not been able to find published formant frequency data for the long vowels of Japanese.

1.2.4 Pitch fall

Some recent studies investigated pitch fall as a cue to differentiate between short and long vowels in Japanese. Nagano-Madsen and Ericsson (1989) examined accented and unaccented words such as: [AmA] (HL) 'heaven' and [AmA] (LH) 'a woman diver', [mAmA] (HL) 'mother' and [mAmA] (LH) 'food', [An] (HL) 'a plan' and [hen] (LH) 'strange'. While they did not mention how they measured the pitch fall, the authors reported that there was a F0 peak and a F0 minimum in an accented mora with HL sequence; that is, there was a pitch fall. Moreover, in an unaccented mora, there was no pitch fall observed. In fact, sometimes a pitch rise was reported in this study.

Kozasa (2005) investigated vowel length differences in terms of the effect of pitch fall and duration. She conducted a production study using accented and unaccented vowels. Two female and two male native speakers of Tokyo Japanese participated in this experiment. She used minimal pairs as follows: [kA:do] (HL.L) 'card' and [kAdo] (H.L) 'corner', [be:P∞] (HL.L) 'veil' and [beP∞] (H.L) 'bell', [bi:P∞] (HL.L) 'beer' and [bi.P∞] (H.L) 'building', [Po:bA] (HL.L) 'elderly woman' and [PobA] (H.L) 'donkey', [k∞:P∞] (HL.L) 'cool' and [k∞P∞] (H.L) 'to come' for accented vowels, and [se:ko:] (HH.HH) 'success' and [seko:] (H.HH) 'construction', [jA:k∞] (HH.H) 'evil' and [shAk∞] (H.H) 'the Japanese foot (a unit of length)' for unaccented vowels. Kozasa (2005) preferred to use HH.HH, H.HH, HH.H and H.H for her test words since although in many dictionaries and literature, the indication of unaccented words are L.H, L.HH, L.HHH, etc, the word initial pitch L is realized H in phrase medial position. That is, when the words are read in a carrier sentence without any pause, the pitch accent in the word initial position of test word would be phonetically H, not L. The participants produced the test words in a

carrier sentence, *sakki* _____ *to iimashita* 'I said _____ just now.' She obtained pitch fall values by measuring the difference between F0 maximum in the target vowel, and F0 minimum in the vowel within the second mora.

The pitch fall for the long vowels was significantly different from that for the short vowels. The pitch fall ratio between short and long accented vowels was 1:1.4. It is clear that the long vowels have a larger pitch fall.

Kozasa (2005) also made an analysis of vowel length in each pitch accent type. She performed a repeated-measures ANOVA on the experiment with accented vowels and with unaccented vowels. The results indicated that the mean durations of vowels in accented and unaccented environments were significantly different. Again the ratio of short and long vowels is 1:2.5 for accented vowels, and 1:2.2 for unaccented vowels. This indicates that long vowels become longer in the unaccented condition. Moreover, the mean durations of short vowels in accented and unaccented conditions are 72 ms and 60 ms. It is clear that the unaccented short vowels are much shorter than the accented ones. This was consistently true across all the subjects.

Kozasa (2005) also examined how native speakers of Japanese use pitch fall to distinguish two different types of vowel length. She measured the highest F0 within a long accented vowel (with HL.) and the lowest F0 in the vowel in the next mora using the same tokens mentioned above. She calculated the difference between the maximum value of F0 in a target vowel and the minimum value of a vowel in the following mora for both short and long vowels. As shown in Table 5, the mean value of pitch fall for short vowels (H.L) was 68 Hz and 96 Hz for long vowels (HL.L) (See Table 4).

Short Vowel	Long Vowel	Ratio (Short : Long)
68 Hz	96 Hz	1:1.41

Table 4. Results of pitch fall from Kozasa (2005)

Kozasa (2005) concluded that native speakers of Japanese use longer durations for both accented and unaccented vowels. Furthermore, when speakers cannot rely on one of the prosodic features, pitch fall in unaccented vowels, they make the duration of the long vowels longer and that of the short vowels shorter.

1.2.5 Focus of the present study

While many studies have investigated the mora as a unit of timing in Japanese (Han 1962, 1994; McCawley 1968, 1977; Homma 1973; Beckman 1982; Kondo 1995; Port, Dalby and O'Dell 1987, Warner and Arai 2001), only a few studies have focused on the acoustic correlates of the Japanese vowel length distinction.

Kozasa (2005) explored the short and long vowel distinction in Japanese in accented and unaccented conditions. However, she used different words in accented and unaccented contexts. In the present study, I consider how different short and long vowels are if the vowels are in compound noun contexts, since when nouns are compounded, the pitch accent pattern changes phonologically within a vowel.

Several researchers (Higurashi; 1983; Tsujimura and Davis, 1987) examined the shift of the phonological accentual pattern of nominal compounds where the second member is one or two morae, and concluded that the accent location of the resulting compound

cannot be predicted based solely on the lexical accent of the two words. The sentences that exemplify this analysis are as follows:

- (a) [kA] 'section' + [jo:] 'for' → [kA. jo:] 'for section'
 H HL L. HH
- (b) [kA:] 'car' + [jo:] 'for' → [kA:. jo:] 'for car'
 HL HL LL. HH

As can be seen, in (b), the accent of the first member is being lost after compounding. The H of the second member, which is [jo:] in the example above, in (a) and (b), is lost and stays as a sequence of HH after compounding. In other words, the phonological literature predicts a phonetic pitch accent neutralization. This phonological neutralization rule allows for the measurement of the same words within both accented and unaccented contexts. The present study uses this procedure to construct the following pitch patterns that are different from Kozasa's (2005), shown in Table 5. Although it is commonly assumed that Japanese accentual phrases tend to start with a L on the first mora and move to a H on the second mora (i.e., LH, LHH, LHHH, LHHHH, etc.), the present study follows Kozasa's (2005) argument that most L pitch in the word initial position are recognized as H in word-medial position as stated earlier. Differently from Kozsa (2005), a notation LL will be used in this study based on the idea of the phonological pitch neutralization model. Note that both LL in this study and HH in Kozasa's study at word initial positions are intended to represent a long vowel with no lexical pitch accent.

	Short	Long
Accented	H. (L)	HL.
Unaccented	L.	LL.

Table 5. Pitch patterns for the present study

The accented short vowel above has a pitch of H, which is considered as accented since it is followed by a pitch of L in the carrier sentence.

The present study also will investigate the pitch neutralization in compound noun context, which has not been done so far. Many studies have examined Japanese word-final pitch accent neutralization (Vance, 1995; Maniwa 2002). Most recently, Maniwa (2002) investigated the acoustic correlates of neutralization of F0 of word-final accented and unaccented words in Japanese. She used test words such as [hAnA-gA] (L.H.L) “flower-Nominative” and [hAnA-gA] (L.H.H) “nose-Nominative,” contrasting to the words without grammatical suffix [gA]; [hAnA] (L.H) ‘flower’ and [hAnA] (L.H) ‘nose.’ Her results showed that the F0 of the final accented and unaccented words with the suffix [gA] was neutralized; that is, there was no significant difference between the two across all eight speakers. On the other hand, with the suffix [gA], the final pitch distinction was evident, indicating that all speakers distinguished the final accented and unaccented F0. To my knowledge, there are few studies that examined the phonetic evidence of the phonological pitch neutralization in Japanese compound noun context.

The focus of the present study is to first examine whether or not the phonological pitch neutralization rule (Higurashi, 1983, Tsujimura and Davis, 1987) is confirmed phonetically. Second, the present study examines the difference between short and long

vowels within Accented and Unaccented contexts. Since Kozasa (2005) and many other studies on Japanese vowel length do not show any clear results for vowel quality or F0 values of both short and long vowels other than pitch fall, I would like to consider vowel quality as well as vowel duration and pitch fall, even though vowel quality was considered to be less important than duration or pitch fall in previous studies. Moreover, Kozasa's (2005) measurement of pitch fall was the difference between F0 maxima in the first vowel and F0 minima in the second vowel within CV₁CV₂ words. This does not show the pitch fall within a target vowel. I will investigate F0 movement within a vowel and how the presence of F0 fall affects the difference between Japanese short and long vowels in the phonological pitch neutralization context.

1.3 Hypotheses

I constructed the following hypotheses:

- (1) The neutralization of F0 between long and short vowels in the unaccented context is complete.
- (2) There is a pitch fall within accented short vowels (**H.**) and long vowels (**HL.**) followed by a pitch of L in the carrier sentence.
- (3) The pitch fall difference in accented long vowels is larger than that in accented short vowels.
- (4) There is no pitch fall in unaccented short and long vowels.
- (5) Pitch onset is higher in accented vowels (**H.**, **HL.**) than unaccented vowels (**L.**, **LL.**).
- (6) Pitch offset is high in accented short vowels (**H.**) and low in the accented

long vowel (**HL.**) and unaccented vowels (**L.**, **LL.**).

- (7) The duration of long vowels will always be longer than that of short vowels.
- (8) The duration of short vowels is shorter in the unaccented context than in the accented context.
- (9) The duration of long vowels is longer in the unaccented context than in the accented context because of the absence of the pitch fall cue even though it is well known that as word length increases, vowel duration decreases.
- (10) The formant frequencies will show a larger difference between short and long vowels in the unaccented context than in the accented context since the vowels will lose the pitch fall cue.

Chapter 2. Experiment

2.1 Methodology

2.1.1 Participants

Four female and four male participants aged between 19 and 31 years served to produce the test words for this study. Speakers from Tokyo or its suburb area were chosen to generate the pitch pattern on each word. The subjects were all native speakers of Japanese from the Kanto Area (the region includes Tokyo and the suburb of Tokyo). They were all graduate or undergraduate students at the University of Kansas. None of the speakers reported any speech or hearing disorders.

2.1.2 Stimuli

The minimal pairs contain the five Japanese vowels, [i], [e], [A], [o], [ɤ] and their long counterparts, in the first mora position. The number of minimal pairs that contained [i] was 5, [e] was 2, [A] was 4, [o] was 4 and [ɤ] was 4. The short vowel members were one-mora words (CV.) with a pitch H, and long vowel members were two-mora words (CV.V) with a HL pitch. The word list that was used for the present study is shown in Table 6.

/V/ H	/V:/ HL	/V jo:/ LHH	/V: jo:/ LLHH
bA ‘place’	bA: ‘bar’	bAjo: ‘for place’	bA:jo: ‘for bar’
bo ‘tomb’	bo: ‘stick’	bojo: ‘for tomb’	bo:jo: ‘for stick’
ni ‘load’	ni: ‘second place’	nijo: ‘for load’	ni:jo: ‘for second place’
ne ‘root’	ne: ‘root’	nejo: ‘for root’	ne:jo: ‘for root’
no ‘field’	no: ‘brain’	nojo: ‘for field’	no:jo: ‘for brain’
n∞ ‘small lake’	n∞: ‘sew’	n∞jo: ‘for small lake’	n∞:jo: ‘for sewing’
hi ‘fire’	hi: ‘to obey law’	hijo: ‘for fire’	hi:jo: ‘for obeying law’
he ‘door’	he: ‘fence’	hejo: ‘for door’	he:jo: ‘for fence’
ho ‘sail’	ho: ‘cheek’	hojo: ‘for sail’	ho:jo: ‘for cheek’
te ‘hand’	te: ‘bank (on a river)’	tejo: ‘for hand’	te:jo: ‘for bank’
to ‘prefecture’	to: ‘ten’	tojo: ‘for prefecture’	to:jo: ‘for ten’
s∞ ‘nest’	s∞: ‘proper name Sue’	s∞jo: ‘for nest’	s∞:jo: ‘for Sue’
Σi ‘city’	Σi: ‘personal opinion’	Σjo: ‘for city’	Σi:jo: ‘for personal opinion’
TΣi ‘ground’	tΣi: ‘position’	tΣijo: ‘for ground’	tΣ:jo: ‘for position’
ts∞ ‘proper name Tsu’	ts∞: ‘expert’	ts∞jo: ‘for Tsu’	ts∞:jo: ‘for expert’
ki ‘tree’	ki: ‘strange’	kijo: ‘for tree’	ki:jo: ‘for strange’
kA ‘section’	kA: ‘car’	kAjo: ‘for section’	kA:jo: ‘for car’
k∞ ‘district’	k∞: ‘eat’	k∞jo: ‘for district’	k∞:jo: ‘for eating’

Table 6. Minimal pairs used in the present study

2.1.3 Procedure

The data collected are from two reading tasks. During the first of these tasks the participants were asked to read minimal pairs such as /kA/-/kA:/ in a carrier sentence (a) *Korewa _____ desu*. “This is _____.” For the second task, subjects read the minimal pairs for each of the short and long vowels in the compounded noun environment in a carrier sentence, (b) *Korewa _____yo: desu*. “This is *for* _____.” These sentences were in randomized order, and all reading materials were presented to subjects in Japanese orthography. Short and long vowels were listed in the same block

randomly. Filler sentences were included as the first and the last sentences on each page to avoid a list effect.

Participants were asked to read the materials in the anechoic chamber at the University of Kansas. They were recorded using a cardioid microphone (Electrovoice RE –20) and a DAT tape recorder (Fostex D5). The data were digitized on a computer using a sampling rate of 22.5 kHz with 16-bit resolution and were analyzed using the speech analysis software Praat (2002).

2.1.4 Measurements

All measurements were also conducted by using Praat (2002) for this study. Vowel duration, F1, F2, F3, pitch onset, pitch offset, pitch fall, consonant duration and word duration were all measured. The vowel onset was defined as the onset of the first formant in the spectrogram. The offset of the vowel was defined as the end of the second formant. Formant frequencies (F₁-F₃) were measured at the middle of the target vowels in the spectrogram. F0 was obtained by extracting pitch contours using Praat. Pitch onset and pitch offset were the F0 values of the onset and the offset of the target vowels, respectively. Pitch fall was the subtraction of pitch offset from pitch onset. The measurement of /i/ in the compound context was difficult since it was followed by the glide /j/. I separated /i/ from /j/ at the point where F2 started rising and F3 started falling within the target vowel for /j/, as reported in previous studies (Xu, 2002; Lehiste and Peterson, 1961; Peterson and Lehiste, 1960). All of the tokens were number-coded for analysis to avoid experimenter bias.

2.1.5 Analyses

Measurements were averaged across the five productions for each speaker. Two-way repeated-measures ANOVAs with Vowel (Short and Long), and Context (Accented and Unaccented) as independent variables, and vowel duration, F1, F2, F3, pitch onset, pitch offset, and pitch fall as dependent variables were conducted. The present study will refer to short and long vowels in the accented context as AS and AL, and in the unaccented context as US and UL, respectively. Paired Samples t-tests were conducted to observe the significance level of the difference between AS-AL, US-UL, AS-US, and AL-UL on each dependent variable. Furthermore, other Paired Samples t-tests were conducted to examine the difference between accented and unaccented vowels for each dependent variable. To test Kozasa's (2005) findings that unaccented short vowels are shorter than accented short vowels, and unaccented long vowels longer than accented long vowels, Paired-Samples t-tests were also conducted for vowel duration for each vowel /i/, /e/, /A/, /o/, /œ/.

2.2. Results

2.2.1 Pitch fall

The mean value of pitch fall across all vowels was 13 Hz for short and 26 Hz for long vowels, 41 Hz for vowels in the accented context, and -2 Hz for vowels in the unaccented context. The pitch fall mean values were 21 Hz for AS, 61 Hz for AL, 5 Hz for US, and -9 Hz for UL (see Table 7).

Pitch fall (Hz)			
	Overall	Short	Long
Overall	20	13	26
Accented	41	21	61
Unaccented	-2	5	-9

Table 7. Mean values for Pitch fall

The main effect of Length was significant ($F(1, 764)=312.195, p=.000$). Long vowels have a larger pitch fall than short vowels. The main effect of Context was also significant ($F(1, 764)=1815.203, p=.000$). Vowels in the accented context have a large pitch fall while those in the unaccented context have none. The interaction between Length and Context was also significant ($F(3, 764)=1035.831, p=.000$). The difference between short and long vowels is much larger in the accented context than in the unaccented context (see Figure 1).

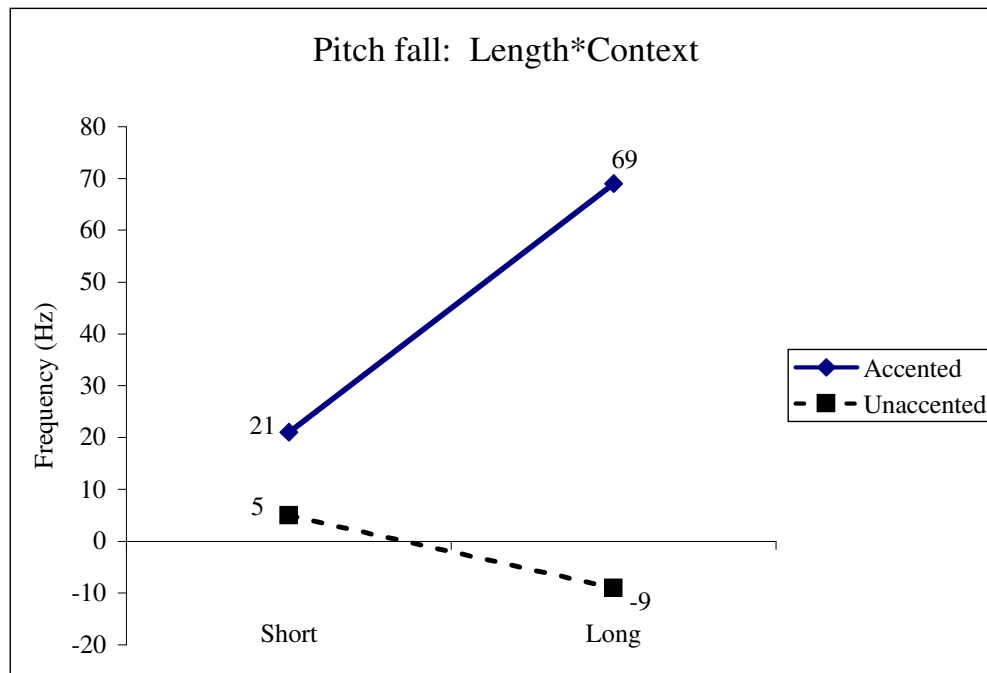


Figure 1. Interaction between Length and Context for Pitch fall

The pitch fall of AS and AL ($t(764)=28.157, p=.000$), AS and US ($t(764)=13.769, p=.000$), and AL and UL ($t(764)=18.309, p=.000$) was significantly different; however, US and UL were not significantly different ($t(764)=38.934, p>.236$). This indicates that pitch fall was neutralized in the unaccented context.

A paired-samples t-test was also conducted on the difference between accented short-long vowels and unaccented short-long vowels. The results showed that there was a significant difference between them ($t(1359)=35.108, p=.000$); that is, the pitch fall difference value is significantly larger between accented short and long vowels.

2.2.2 Pitch onset

The mean value of pitch onset across all vowels was 204 Hz for short vowels and 211 Hz for long vowels, and 224 Hz and 190 Hz for vowels in the accented and unaccented contexts, respectively. The mean pitch onset values were 222 Hz for AS, 225 Hz for AL, and 184 Hz for US, and 196 Hz for UL, respectively (see Table 8).

Pitch onset (Hz)			
	Overall	Short	Long
Overall	207	204	211
Accented	224	222	225
Unaccented	190	184	196

Table 8. Mean values of Pitch onset

There was a significant main effect of Length on pitch onset ($F(1, 764) = 45.648, p = .000$). Long vowels had a significantly higher pitch onset than short vowels. There was also a significant main effect of Context on Pitch onset ($F(1, 764) = 661.009, p < .010$). Accented vowels had a significantly higher pitch onset than unaccented vowels. The interaction between Length and Context was also significant ($F(1, 764) = 17.214, p = .000$) (see Figure 2).

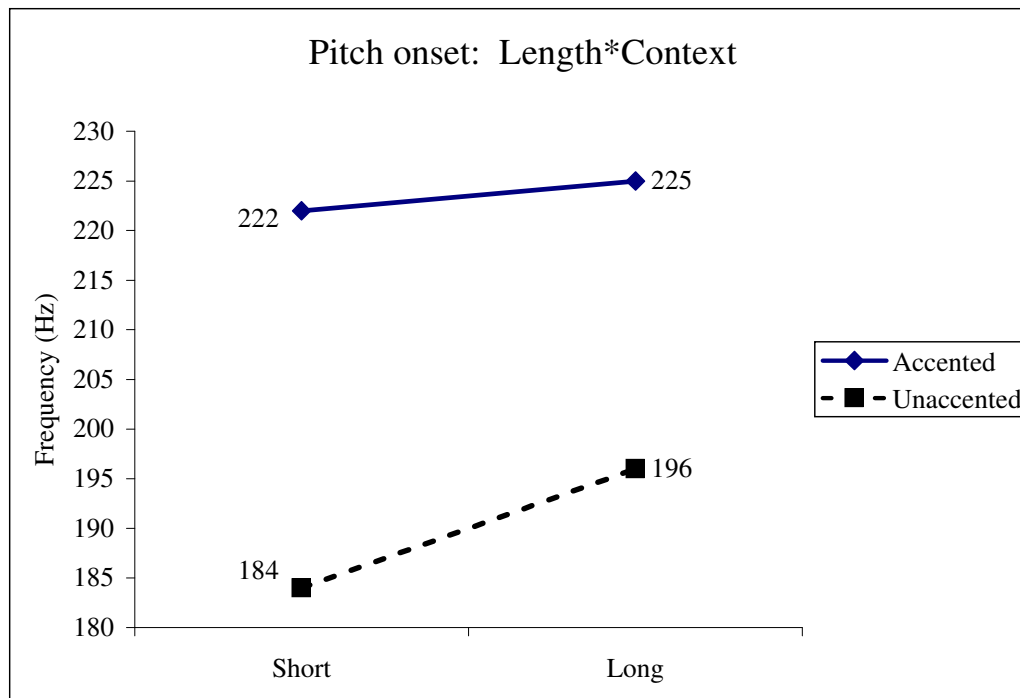


Figure 2. Interaction of Length and Context for Pitch onset

The pitch onset of all the pairs, AS and AL ($t(764)=3.916, p=.000$), US and UL ($t(764)=5.799, p=.000$), AS and US ($t(764)=37.562, p=.000$), and AL and UL ($t(764)=13.629, p=.000$) was significantly different. Pitch onset was higher in the accented context than in the unaccented context.

A paired-sample t-test was also conducted on the difference between accented short-long vowels and unaccented short-long vowels. The results showed that there was a significant difference between them ($t(1359)=23.371, p=.000$); that is, the difference between unaccented short and long vowels is significantly larger than that between accented short and long vowels.

2.2.3 Pitch offset

The mean value of pitch offset across all vowels was 190 Hz for short vowels and 184 Hz for long vowels, and 183 Hz for vowels in the accented context and 191 Hz for vowels in the unaccented context. The mean values were 202 Hz for AS, 165 Hz for AL, 179 Hz for US, and 204 Hz for UL, respectively (see Table 9).

Pitch offset (Hz)			
	Overall	Short	Long
Overall	187	190	184
Accented	183	202	165
Unaccented	191	179	204

Table 9. Mean Pitch offset values

The effect of Length on pitch offset was significant ($F(1, 764) = 18.694, p = .000$). Pitch offset was significantly lower for long vowels across all vowels. The effect of Context was significant for pitch offset ($F(1, 764) = 42.145, p = .000$). Pitch offset was significantly higher in the unaccented context. The interaction of Length and Context was also significant ($F(1, 764) = 488.312, p = .000$) (See Figure 3).

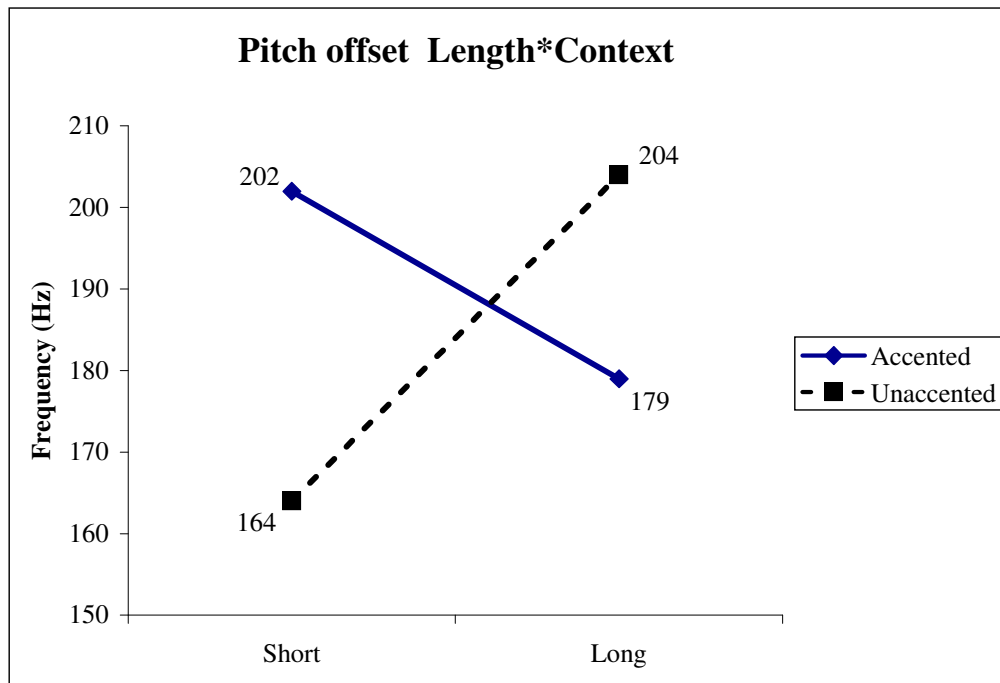


Figure 3. Interaction of Length and Context for Pitch offset.

The pitch offset of all the pairs: AS and AL ($t(764)=31.103, p=.000$), US and UL ($t(764)=10.270, p=.000$), AS and US ($t(764)=24.404, p=.000$), and AL and UL ($t(764)=15.543, p=.000$) was significantly different.

A paired-samples t-test was also conducted on the difference between accented short-long vowels and unaccented short-long vowels. The results showed that there was a significant difference between them ($t(1359)=5986, p=.000$); that is, the difference in pitch offset between accented short and long vowels is significantly greater than that between unaccented short and long vowels.

2.2.4 Vowel duration

The mean duration across all the vowels was 71 ms for short vowels, 190 ms for long vowels, 140 ms for accented vowels and 121 ms for unaccented vowels. The mean durations were 85 ms and 195 ms for AS and AL and 57 ms and 184 ms for US and UL, respectively. The ratio of short and long vowels was 1:2.7 for short and long vowels in general, 1:2.3 in the accented and 1: 3.2 in the unaccented context (see Table 10).

Vowel duration (ms)				
	Overall	Short	Long	Ratio Short : Long
Overall	130	71	190	1: 2.7
Accented	140	85	195	1: 2.3
Unaccented	121	57	184	1: 3.2

Table 10. Mean vowel duration values and ratios

Statistical analysis showed that vowel duration was significantly affected by Length. The difference between short and long vowels was significant ($F(1, 764)=4350.636$, $p=.000$). Long vowels were always longer than short vowels. There was no significant main effect of Context on vowel duration ($F(1, 764)=2.733$, $p=.097$). The durations of accented and unaccented vowels do not differ depending on the contexts. There was a significant interaction of Length and Context ($F(1, 764)=7.101$, $p<.008$) (see Figure 4).

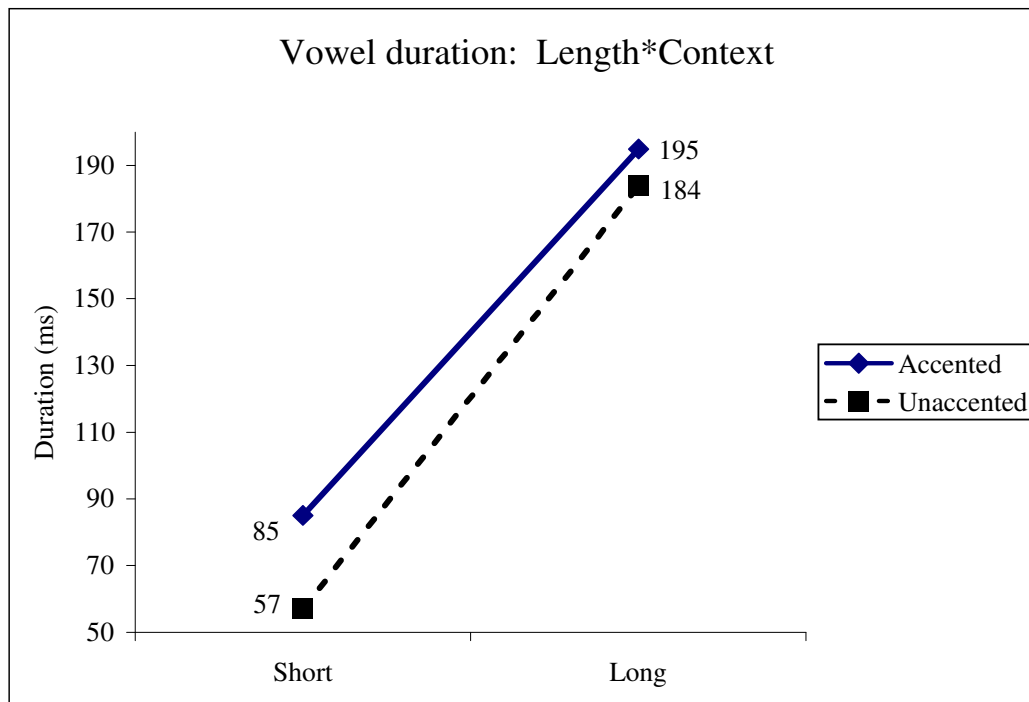


Figure 4. Interaction of Length and Context for vowel duration

The mean durations of each of the five short vowels in the accented context and in the unaccented context were 67 ms and 57 ms for [i], 85 ms and 72 ms for [e], 96 ms and 44 ms for [A], 98 ms and 56 ms for [o], and 76 ms and 47 ms for [∞], respectively. The mean durations of each of the five long vowels in the accented context and unaccented context were 180 ms and 205 ms for [i:], 195 ms and 165 ms for [e:], 209 ms and 153 ms for [A:], 198 ms and 165 ms for [o:], and 186 ms and 153 ms for [∞:], respectively.

The vowel duration of AS and AL ($t(764)=99.185, p=.000$), US and UL ($t(764)=49.279, p=.000$), and AS and US ($t(764)=19.073, p=.000$), AL and UL ($t(764)=11.997, p=.000$) was significantly different.

A paired-samples t-test was also conducted on the difference between accented short-long vowels and unaccented short-long vowels. The results showed that there was a

significant difference between them ($t(1359)=12.501, p=.000$); that is, long vowels in the unaccented context are longer, and the ratio of the short-long vowels is significantly larger for the unaccented vowels.

2.2.5 *F1*

The mean *F1* values across all vowels were 423 Hz for short vowels and 429 Hz for long vowels, and 451 Hz for vowels in the accented context and 401 Hz for vowels in the unaccented context. The mean *F1* values were 457 Hz and 446 Hz for AS and AL, 389Hz and 414 Hz for US and UL (see Table 11).

F1 (Hz)			
	Overall	Short	Long
Overall	426	423	429
Accented	451	457	446
Unaccented	401	389	414

Table 11. Mean values of *F1*

There was a significant main effect of Length on *F1* ($F(1, 764)=6.148, p<.013$). Long vowels had a significantly higher *F1* than short vowels. There was a significant main effect of Context on *F1* ($F(1, 764)=313.360, p=.000$). *F1* is significantly higher in the accented context than in the unaccented context. The interaction of Length and Context for *F1* was significant ($F(1, 764)=65.711, p=.000$) (See Figure 5). The difference in *F1* between the accented and unaccented context is significantly greater in short as compared to long vowels.

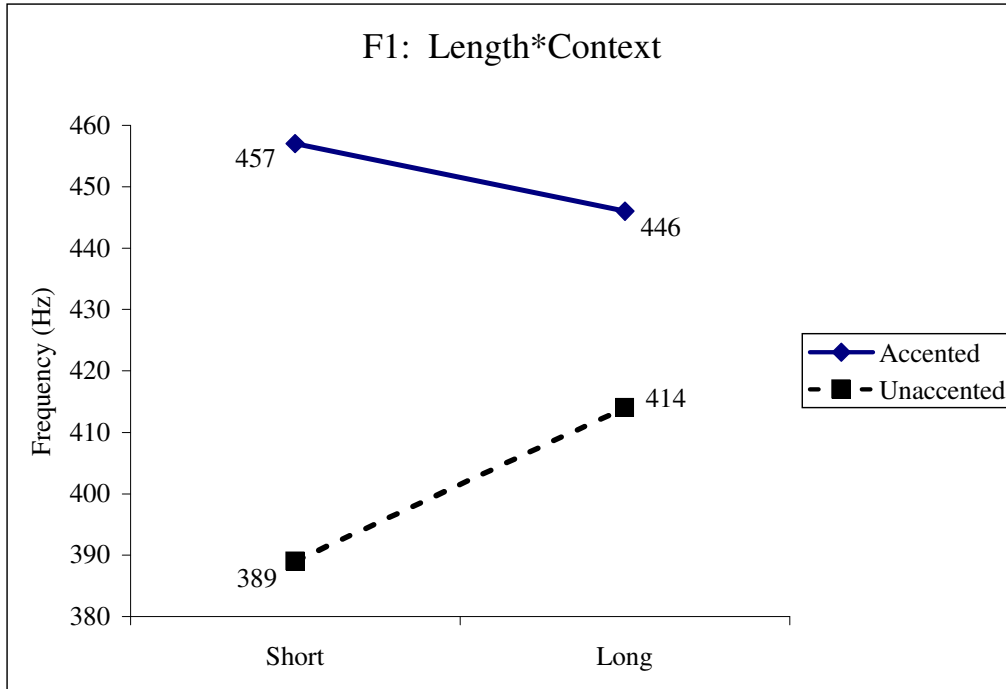


Figure 5. Interaction of Length and Context for F1

The mean F1 values of each short vowel in the accented and the unaccented context were 348 Hz and 305 Hz for [i], 534 Hz and 410 Hz for [e], 795 Hz and 758 Hz for [A], 507 Hz and 452 Hz for [o], and 409 Hz and 336 Hz for [∞], respectively. The mean F1 of long vowels in the accented and the unaccented contexts was 342 Hz and 320 Hz for [i], 534 Hz and 478 Hz for [e], 809 Hz and 764 Hz for [A], 497 Hz and 463 Hz for [o], and 412 Hz and 440 Hz for [∞], respectively.

The F1 of all AS and AL ($t(764)=3.560, p=.000$), US and UL ($t(764)=6.771, p=.000$), AS and US ($t(764)=16.920, p=.000$), AL and UL ($t(764)=10.342, p=.000$) was significantly different.

A paired-samples t-test was also conducted on the difference between accented short-long vowels and unaccented short-long vowels. The results showed that there was a

significant difference between them ($t(1359)=19.029, p=.000$); that is, the difference between short and long vowels is significantly larger in the unaccented context.

2.2.6 F2

The general F2 values across all the vowels were 1876 Hz for short and 1852 Hz for long vowels, and 1858 Hz for vowels in the accented and 1871 Hz for vowels in the unaccented contexts. The mean F2 values were 1842 Hz and 1873 Hz for AS and AL, and 1910 Hz and 1831 Hz for US and UL, respectively (see Table 12).

F2 (Hz)			
	Overall	Short	Long
Overall	1864	1876	1852
Accented	1858	1842	1873
Unaccented	1871	1910	1831

Table 12. F2 mean values

There was a significant main effect of Length on F2 ($F(1, 764)= 5.968, p<.015$). Short vowels had a significantly higher F2 than long vowels. There was also a significant effect of Context on F2 ($F(1, 764)=3.904, p<.049$). Unaccented vowels had a significantly higher F2 than accented vowels. The interaction of Length and Context was significant ($F(1, 764)= 81.462, p=.000$) (see Figure 6). While unaccented short vowels had a lower F2 than Unaccented long vowels, Accented short vowels had a higher F2 than Accented long vowels. This interaction for F1 and F2 to be significant is assumed that the location where F2 was measure, which was the middle point of the target vowels, was closer in short vowels to the suffix [jo:] which contains high F2 in /j/; that is, short vowels were more affected by the F2 of following /j/.

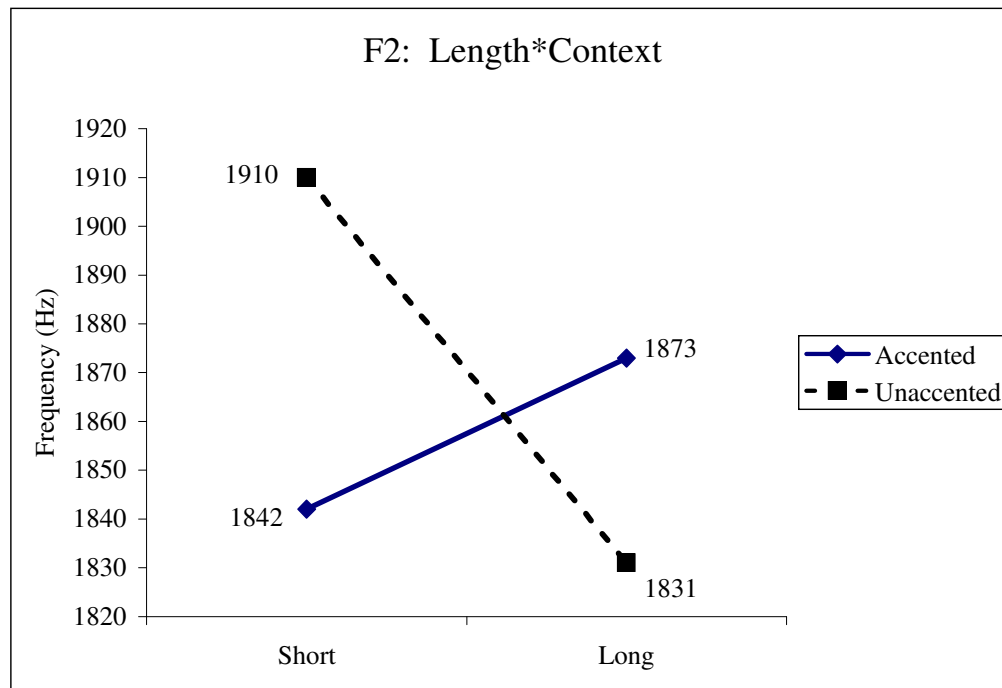


Figure 6. Interaction of Length and Context for F2

The mean F2 values of each of the five short vowels in the accented and unaccented contexts were 2456 Hz and 2499 Hz for [i], 2231 Hz and 2373 Hz for [e], 1521 Hz and 1601 Hz for [A], 1052 Hz and 1105 Hz for [o], 1648 Hz and 1881 Hz for [∞], respectively. The mean F2 values of each of the five long vowels in the accented and unaccented contexts were 2620 Hz and 2591 Hz for [i], 2369 Hz and 2317 Hz for [e], 1375 Hz and 1373 Hz for [A], 860 Hz and 827 Hz for [o], and 1572 Hz and 1548 Hz for [∞], respectively.

The F2 of all AS and AL ($t(764)=7.611, p=.000$), AS and US ($t(764)=6.715, p=.000$), AL and UL ($t(764)=6.596, p=.000$) and US and UL ($t(764)=5.812, p=.024$) was significantly different.

A paired-samples t-test was also conducted on the difference between accented short-long vowels and unaccented short-long vowels in terms of F2. The results showed that there was a significant difference between them ($t(1359)=3.247, p<.001$); that is, the difference between short and long vowels is significantly larger in the unaccented context.

2.2.7 F3

Table 6 shows the mean value of F3 across all vowels. F3 was 3055 Hz and 3096 Hz for short and long vowels, and 3100 Hz and 3051 Hz for vowels in the accented and the unaccented contexts, respectively. The mean values of F3 were 3068 Hz for AS, 3132 Hz for AL, 3041 Hz for US, and 3060 Hz for UL (see Table 13).

F3 (Hz)			
	Overall	Short	Long
Overall	3075	3055	3096
Accented	3100	3068	3132
Unaccented	3051	3041	3060

Table 13. Mean values of F3

The main effect of Length was significant for F3 ($F(1, 764)= 237.591, p=.000$). F3 of long vowels is higher than that of short vowels. The main effect of Context on F3 was significant ($F(1, 764)=45.486, p=.000$). Accented vowels have a higher F3 than unaccented vowels. The interaction of Length and Context for F3 was also significant ($F(1, 764)= 13.235, p=.000$). The difference between short and long vowels was greater in the accented context than in the unaccented context. (See Figure 7).

The mean F3 values of each of the five short vowels were 3407 Hz and 3403 Hz for [i], 2999 Hz and 3186 Hz for [e], 2868 Hz and 2809 Hz for [A], 2940 Hz and 2845 Hz for [o], and 2933 Hz and 2800 Hz for [∞], in the accented and the unaccented contexts, respectively. The mean F3 values of each of the five long vowels were 3550 Hz and 3500 Hz for [i], 3146 Hz and 3103 Hz for [e], 2836 Hz and 2800 Hz for [A], 3025 Hz and 2960 Hz for [o], and 2917 Hz and 2867 Hz for [∞], in the accented and unaccented contexts, respectively.

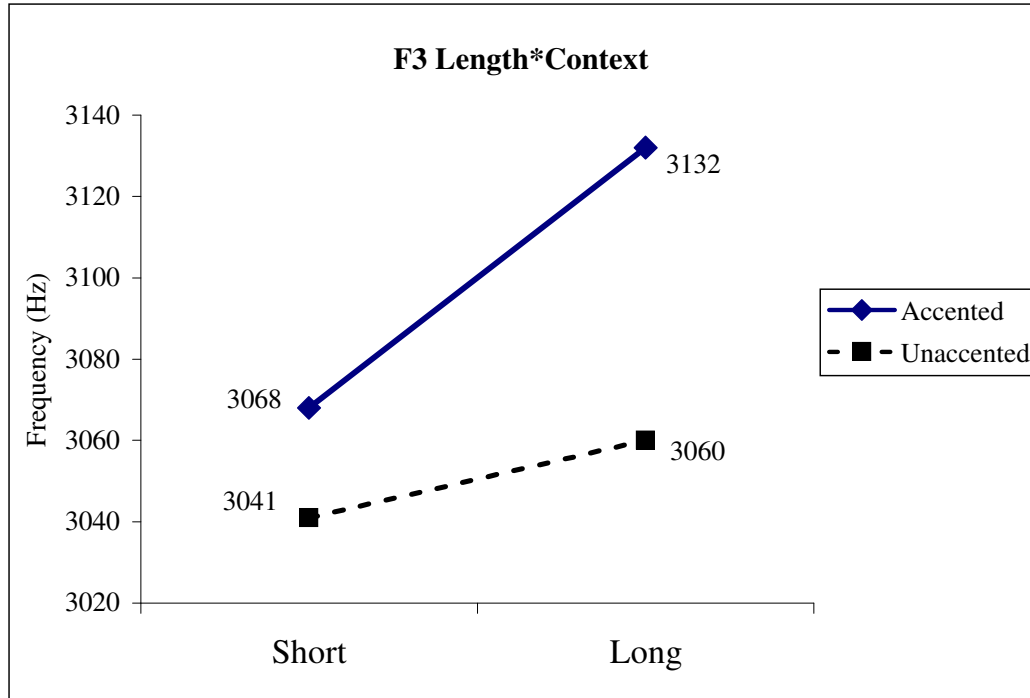


Figure 7. Interaction of Length and Context for F3

The F3 of all AS and AL ($t(764)=7.611, p=.000$), US and UL ($t(764)=1.971, p<.049$), AS and US ($t(764)=2.935, p<.003$), AL and UL ($t(764)=7.202, p=.000$) was significantly different.

A paired-samples t-test was also conducted on the difference between accented short-long vowels and unaccented short-long vowels. The results showed that there was a significant difference between them ($t(1359)=6.023, p=.000$); that is, the difference between short and long vowels is significantly larger in the accented context.

Chapter 3 Discussion and Conclusion

3.1 Discussion

The data presented in the previous chapter demonstrate a number of new findings, and some of these findings have not been considered in previous studies.

First, the phonological pitch neutralization in a compound noun context, namely the unaccented context, was not complete as indicated by a significant difference in terms of pitch onset and pitch offset. However, the compound noun context neutralized the pitch fall completely. There was a larger pitch fall within accented long vowels than accented short vowels, whereas there was none within unaccented short and unaccented long vowels. The mean pitch fall value of accented long vowels was 61 Hz, while it was 21 Hz for accented short vowels, and 5 Hz for unaccented short vowels and -9 Hz for unaccented long vowels. This proves that hypotheses (2) and (4) are true: there is a pitch fall in accented vowels, but not in unaccented vowels. Hypothesis (3) is also true; the pitch fall in accented long vowels is larger than in accented short vowels. As expected, unaccented vowels showed no pitch fall although the F0 (pitch onset and offset) value itself had a statistically significant difference of about 7 Hz between unaccented short and long vowels. It can be concluded that the phonological pitch neutralization rule for the Japanese compound noun context phonetically neutralized the pitch fall, but not the F0 onset or offset value; therefore, the neutralization was incomplete, which disagrees with hypothesis (1) (see Figure 8).

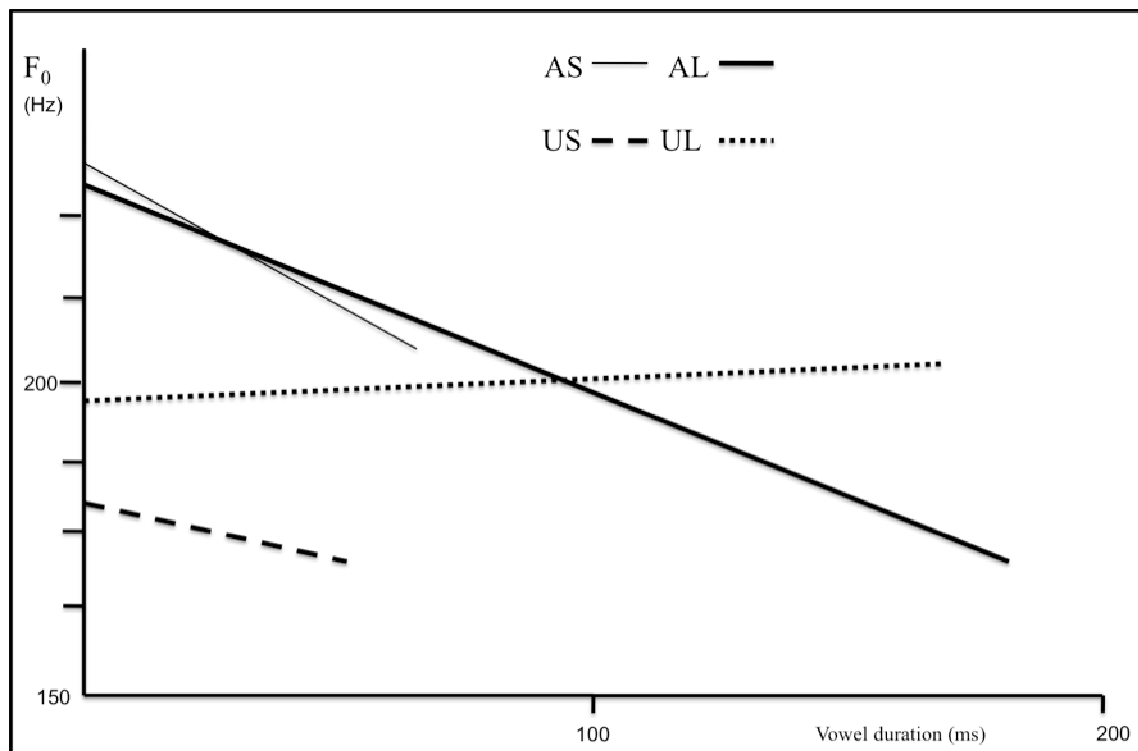


Figure 8. Pitch contour of AS, AL, US, and UL

As the results showed, the pitch onset of target vowels was higher in the accented vowels, which agrees with hypothesis (4). The mean value of pitch onset for unaccented short vowels was 12 Hz lower (184 Hz) than that of unaccented long vowels (196 Hz), whereas accented vowels had only a 3 Hz difference (222 Hz for short vowels and 225 Hz for long vowels.). Long vowels had higher pitch onset in both accented and unaccented contexts than their short counterparts, and as noted above, the difference between short vowels and long vowels in the two contexts was significantly different (3 Hz for accented and 38 Hz for unaccented). Pitch onset was lower when the vowels were in the unaccented context, which agrees with hypothesis (5); furthermore, it was much lower in short vowels. Although unaccented short and long vowels shared an L pitch for

the onset of the test words, the mean pitch onset value of unaccented long vowels was significantly higher than that of unaccented short vowels. According to Venditti (2005), this is due to the weak tone of the post-pause accentual phrase-initial mora. The accentual phrase that is tonally defined in Japanese is consisted of an initial rise to a high around the second mora in the phrase, then it falls towards the right edge of the phrase gradually. When accentual phrase-initial mora is either (1) heavy (i.e. two morae) or sonorant; (2) accented, display a rise starting from a higher F0 level than phrases starting with unaccented light (i.e. single) mora, an additional phenomenon occurs. In either one of the above condition, the first mora with a L pitch is transcribed using J-ToBI as w%L when it occurs at the post-posal phrases; that is, when the first mora is a long vowel or accented, the L pitch is weak when it is pronounced after a pause within an accentual phrase, which all the speakers did for the production study. The L within the long vowels is not as low in other conditions, such as within short vowels (Venditti, 2005), therefore, it is possible that the difference of the F0 value of the first mora with a w%L and a H in the next mora are closer than the difference between normal an L and a H.

The difference of short and long vowels in terms of pitch offset was 37 Hz for the accented context and 25 Hz for the unaccented context. Pitch offset was lower in accented long vowels than in accented short vowels due to the pitch L within long vowels at the offset of the target vowels, which agrees with hypothesis (6). Pitch offset was higher in unaccented long vowels than in unaccented short vowels. Long vowels were generally 119 ms longer than short vowels, and the ratio of short and long vowels was 1:2.7. These results confirm hypothesis (7). When unaccented, short and long vowels were shorter than their unaccented counterparts by 28ms and 10ms, respectively,

confirming hypothesis (8). There was a significant difference between accented and unaccented short vowels, which agrees with hypothesis (7) and Kozasa's (2005) results. Moreover, the difference between short and long vowels was significantly smaller in the accented context. The difference between AS and AL was 110 ms and that between US and UL was 127 ms. The ratio for AS and AL is 1:2.3, and 1:3.2 for US and UL. All the differences were significant. The ratio for the accented context agrees with previous studies (Han 1962, Isei-Jaakkola 2004) that had investigated short and long vowels in the accented (isolation) context. However, the results contradict Homma's (1973) finding that pitch accent does not affect vowel duration. The vowels with LL were shorter than the ones with HL, which disagrees with hypothesis (9). The ratio of accented and unaccented short-long vowels was 1:2.3 and 1:3.2 respectively. This also disagrees with Kozasa (2005) and Hirata (2002): the ratio of accented short-long vowels: 1:2.5 for Kozasa (2005) and Hirata (2003, 2004) was smaller than that of unaccented short-long vowels: 1:2.2 for both Kozasa (2005) and Hirata (2003, 2004). Hypothesis (9) was not true since the duration of long vowels in the unaccented context was shorter than in the accented context.

When the sets of data were analyzed in terms of vowel quality, they showed interesting results. F1 in the accented context had a higher value in short vowels than long vowels; however, in the unaccented context, short vowels had a lower F1 than long vowels. F1 for vowels in the unaccented context was 50 Hz lower than in the accented context. When Paired Samples t-tests were conducted, the results showed that F1 was lower in the unaccented context than in the accented context across all five vowels. F1

was 66 Hz lower in accented long vowels and 32 Hz lower in unaccented long vowels.

Both differences were statistically significant

As for F2, two-way repeated measures ANOVAs showed that the main effects of both Length and Context were significant. The interaction of Length and Context was also significant. Overall, F2 was 24 Hz higher in short vowels than in long vowels. F2 in the unaccented context was 13 Hz higher than in the accented context; moreover, the difference was statistically significant. The difference between short and long vowels in the accented context was much smaller than in the unaccented context: 68 Hz for AS and AL, and 42 Hz for US and UL. Moreover, F2 was 68 Hz higher in accented long vowels, whereas in unaccented long vowels it was 42 Hz lower. The difference between short and long vowels was significant for both accented and unaccented vowels. F2 in Unaccented short vowels is much higher than for any of the other 3 conditions. This may be because the midpoint at which the formant frequencies were measured is much closer to /j/, which raises F2, in short vowels as compared to long vowels.

F3 was 41 Hz higher in long vowels and was 51 Hz higher in the unaccented context. The F3 difference between AS and AL was 64 Hz, and the F3 difference between US and UL was 19 Hz. The vowel charts for short and long vowels in the accented and unaccented contexts can be seen below (see Figure 9).

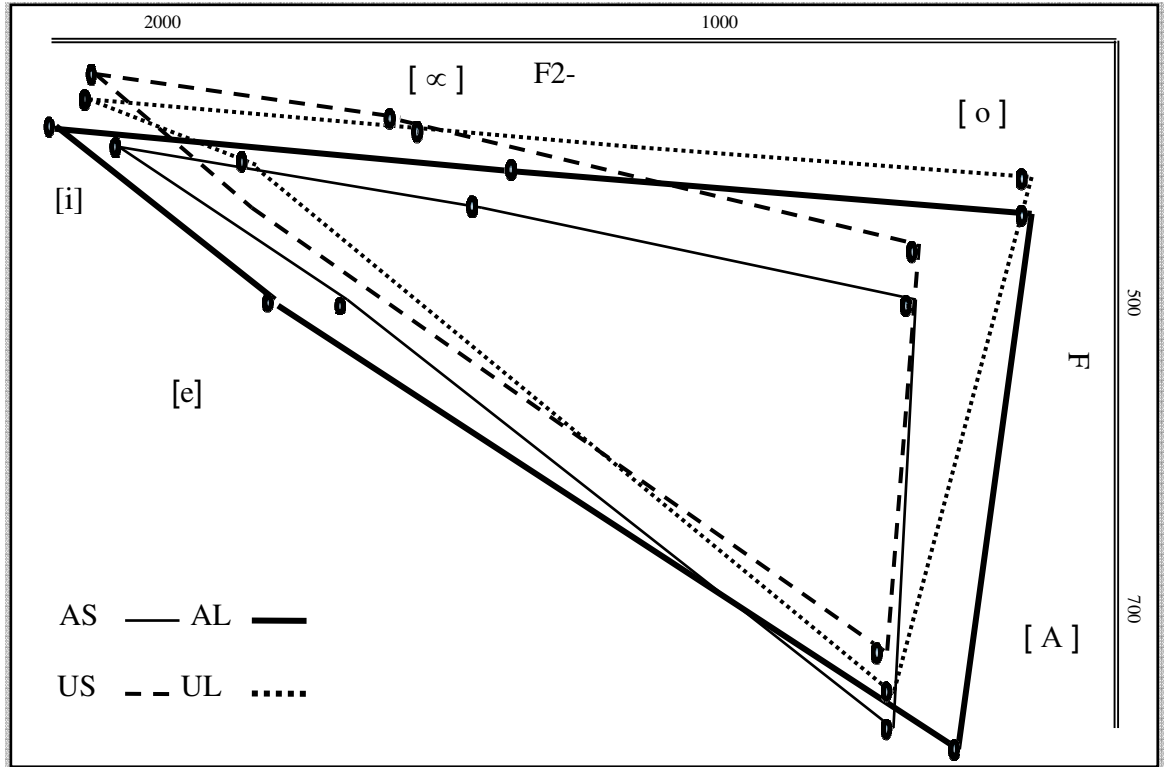


Figure 9. Vowel charts for accented and unaccented short and long vowels.

Whereas most of the previous studies (Han 1962, Homma 1973, and Kozasa 2005) concluded that there were only few differences between short and long vowels, F1, F2 and F3 all three significantly differed between short and long vowels in both the accented and unaccented contexts. This is a new finding of the present study. When vowels were unaccented, the speakers showed larger differences between short and long vowels in vowel quality in F1 and F2, presumably due to the lack of pitch fall. This partially agrees with hypothesis (10).

3.2 Conclusion

The present study investigated acoustic differences between short and long vowels that are accented and unaccented. Previous studies (Nagano-Madsen and Eriksson, 1989; Hirata 2004; and Kozasa 2005) examined the difference between short and long vowels; however, their measurements did not analyze the relationship between vowel length and pitch accent. Tsujimura (1996) and other researchers (Higurashi, 1983; Tsujimura and Davis, 1987) introduced a phonological pitch neutralization context, namely the compound noun context. The present study used this context so that the difference between short and long vowels could truly be compared. This procedure also enabled me to determine whether the phonological pitch neutralization within the compound noun context was complete. The findings showed that the compound context neutralized the pitch fall that existed within accented vowels, but not the F0 onset and offset values themselves from H to L. Thus, it can be concluded that the compound noun pitch neutralization is phonetically incomplete in terms of F0, but complete in terms of pitch fall. Pitch fall was observed within both short and long vowels in the accented context, but not in the unaccented context; moreover, the difference in pitch fall between unaccented short and long vowels was not statistically significant. This proves that the pitch fall is successfully neutralized in the unaccented context with the suffix [jo:].

Long vowels are 2.7 times longer than short vowels. The vowels are significantly longer in the accented context across all vowels. Vowel quality differs between both accented and unaccented short and long vowels. F1 is 50 Hz lower in unaccented vowels than in accented vowels, and long vowels in the unaccented context are 25 Hz higher than their short counterparts while the difference in the accented context was much smaller:

11Hz and 25 Hz in the accented and unaccented contexts, respectively. F2 is 79 Hz lower in unaccented long vowels than in unaccented short vowels. The difference between short and long vowels was much larger in the unaccented context: 31Hz and 79 Hz in the accented and unaccented contexts, respectively. F3 is 49 Hz higher in the accented context. The difference between long and short vowels was much larger in the accented context for F3: 64 Hz and 19 Hz in the accented and unaccented contexts, respectively. F1, F2 and F3 all showed a significant difference between all the possible pairs: accented short and long vowels, and unaccented short and long vowels. It could be concluded that the difference between short and long vowels is also carried by formant frequency for both accented and unaccented vowels whether or not the cue of pitch fall exists. However, the difference becomes larger when vowels are in the unaccented context for F1 and F2 but smaller for F3. Overall, then, it can be concluded that speakers had larger differences in formant frequency when the pitch fall cue was absent, that is, in the unaccented context.

In future studies, it will be meaningful to conduct a perceptual study to investigate if and how native speakers of Japanese differentiate the short and long vowels within the two contexts. Arai et al. (2001) concluded that pitch fall is a stronger cue than duration. It would be interesting to investigate whether there is a difference between the perception of short and long vowels in the simple and in the compound contexts.

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